Syllabus
EES 3310/5310: Global Climate Change

Jonathan Gilligan
Vanderbilt University

Spring 2021

Contents

1 Nuts and Bolts

1.1 Class Meetings

MWF 9:10–10:00 on Zoom
Laboratory: Mondays, 2:10–5:00 PM on Zoom

1.2 Professor

Jonathan Gilligan
Associate Professor of Earth & Environmental Sciences
Associate Professor of Civil & Environmental Engineering
jonathan.gilligan@vanderbilt.edu
www.jonathangilligan.org
Office Hours: On Zoom, Tues. 10:10–11:00 AM, Wed. 8:00–9:00 PM, or by appointment.

1.3 Teaching Assistant

Cameron de Wet
cameron.de.wet@vanderbilt.edu
Office Hours: On Zoom, Thurs. 9:00–10:00 AM, Fri. 1:00–2:00 PM, or by appointment.

Mr. de Wet will be grading labs and homework, so address questions about your homework and lab grades to him.

1.4 Email

If you want to communicate with Professor Gilligan or Mr. de Wet be sure to begin the subject line of your email with "EES 3310" or "EES 5310". This helps assure that we will see your message quickly and respond to it.

I have set my email reader to flag all messages like this as important, so I will read them first. This also assures that I do not mistake your email for spam. I typically receive over 100 emails per day, so if you do not follow these instructions I may not notice your email.

2 Course Description

2.1 Catalog Description

Scientific principles and policy applications. Earth's past; evidence of human impact; future climate change; and economic, social, and ecological consequences. Economic, technological, and public policy responses. Repeat credit for 2110. Students who have earned credit for 2110 will earn only one credit hour for this course. Prerequisite: one of 1030, 1080, 1510, BSCI 1510, CHEM 1601, ECON 1010, ES 1401 or PHYS 1501, 1601, 1901. [4] (MNS)

2.2 Narrative Description

This course will study earth's climate and the way it has changed throughout our planet's history. We will study:

- Determinants of climate: What factors affect climate, how do we know this, and how certain are we?
- Scientific evidence about past climates: What do we know, how do we know it, and how certain are we?
- Natural climate change in earth's history.
- Effects of human activity on global climate in the last 200 years.
- What do we know about future climate change and how will it affect the quality of people's lives?
- How do economists and political scientists assess the costs of climate change and the value of policies to limit it?
- What can we do to mitigate future global climate change or adapt to life in a different climate?
- What is happening politically, both in the U.S. and internationally, to respond to climate change?

3 Goals for the Course

My goals for this course are that at the end of the semester:

- You will have a solid quantitative understanding of the basic physical and chemical principles that control the system and be able to apply that knowledge to reasoning about the climate system and its response to disturbances.
- You will have working familiarity with a variety of computer models that simulate various aspects of the climate system and be able to use those models to explore the implications of scientific principles that are too complex to calculate with pencil and paper.
- You will have a solid scientific understanding of what scientists know, what they don't know, and how they know what they know about how climate works, how and why it has changed in the past, and how it may change in the future.

- You will be able to evaluate the evidence for and against the idea that human activity is warming the planet and assess for yourself whether the evidence is persuasive.
- You will be familiar with the ways economists and policy analysts approach the problem of climate change and public policies that respond to it.
- You will understand the history of scientific and political concern and activity around global warming, the principal policy measures being considered to address climate change, and their major strengths and weaknesses.
- You will have the tools and knowledge to make informed decisions about what climate policies you support or oppose.
- In the laboratory, you will learn to:
  - Use simple climate models to explore the dynamics of the climate system.
  - Use open-source statistical tools to download and analyze real climate data.
  - Follow established reproducible research practices.

When you leave this course, you will not be qualified to work as a climate scientist, but you will be able to follow and critically evaluate news reporting about climate change and climate policy, debate intelligently and knowledgeably, and be an informed voter.

I do not care whether you agree with me politically. I respect people who think for themselves. **What counts is whether you can present your own position clearly and support it with solid evidence and reasoned argument.**

4 Structure of the Course:

I divide the semester into two parts:

1. **Scientific Principles of Climate**: For the first half of the semester, we will focus on the scientific principles of climate and natural climate change in earth's past. This will be very mathematical, using basic algebra. We do not use calculus or other advanced math in this class, but you should be comfortable with simple algebraic equations. We will then look at climate change in the last two centuries and what might happen over the next several centuries. We will emphasize examining the scientific evidence to understand what it can and cannot tell us.

2. **Human Dimensions of Climate Change: Politics, Economics, etc.:** For the second half of the semester, we will focus on the political, economic, and social aspects of climate change and possible public policy and technological responses.

4.1 Laboratory

The laboratory section of this course is very important. In the first half of the semester, you will use interactive computer models of the climate system to explore the implications of principles that we cover in class and in the reading, practice downloading and analyzing real climate data, and learning about best practices for reproducible research in order to make your work reliable, reproducible, and trustworthy.

In the second half, you will use computational tools to explore the challenges of replacing fossil fuels with clean energy (renewable or nuclear), conduct quantitative economic analyses of different kinds of climate policies, and engage in role-playing exercises to simulate the way different climate policies work in practice.

I recommend that you attend the scheduled laboratory meetings on Zoom if you can, but to accommodate students who will be taking the course asynchronously, we will be recording the laboratory sessions so you can watch presentations on your own schedule.

Mr. de Wet and Prof. Gilligan will both have office hours when you can drop in and discuss the laboratories, and if you are not able to attend the scheduled lab times, I highly recommend that you take advantage of our office hours.

Whether you are taking the lab synchronously or asynchronously, I highly recommend that you read all of the reading material for the lab before you show up to the Zoom session or start watching the recording. You will get much more out of the labs if you are prepared.

4.2 Reading Material

There are three required textbooks and one recommended book. Supplementary reading on the Internet or in handouts will also be assigned during the term and posted on Brightspace.

REQUIRED READING MATERIALS

- David Archer, *Global Warming: Understanding the Forecast,* 2nd ed. (Wiley, 2011; ISBN 978-0-470-94341-0). Be sure you get the second edition because it is significantly different from the first.

- William Nordhaus, *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World* (Yale, 2013; ISBN 978-0-300-21264-8)

- Roger A. Pielke, Jr., *The Climate Fix* (Basic Books, 2010; ISBN 978-0-465-02519-0)

There is a companion web site to *Global Warming: Understanding the Forecast* at `climatemodels.uchicago.edu`, which includes interactive on-line computer models that we will use for some exercises in the book.

RECOMMENDED READING MATERIALS

- Hadley Wickham and Garrett Grolemund, *R for Data Science* (O'Reilly, 2017; ISBN 978-1-491-91039-9). This book is also available as a free online edition at `r4ds.had.co.nz/`.

OVERVIEW OF READING MATERIALS

I will give out detailed reading that give specific pages to read for each class and notes on important things you should understand. **I expect you to complete the reading before you come to class or watch the recorded class session on the day for which the reading is assigned**, so you can participate in discussions of the assigned material and ask questions if there are things you don't understand.

While science aims to give correct answers to scientific questions, there are not right or wrong answers to questions of what is the best economic model with which to assess the costs of climate change or the best policy with which to respond to climate change, so I have chosen books and other reading material that present different points of view on the political and economic aspects.

4.3 Graded Work

BASIS FOR GRADING

Class participation	15%
Laboratory & Homework	55%
Final exam	30%

PARTICIPATION

To make sure that people who are taking the course asynchronously have lots of opportunity to participate in discussions, I will be putting discussion questions on the Brightspace discussion board each week and you will get participation credit for posting on the discussion boards and responding to other students' posts.

I am also setting up discussion boards for questions about the readings and lectures and labs. I encourage you to ask on those boards about anything that you didn't understand or thought was unclear, or would like to see me cover in greater detail in future classes.'

TESTS AND EXAMINATIONS

FINAL EXAMINATION:

There will be an open-book take-home final exam, for which you may use your books and notes. You will submit your take-home final electronically on Brightspace. The final exam is due by the end of the scheduled alternate final examination, 2:00 pm Monday May 10.

The final exam will be cumulative over all the material covered during the term.

5 Honor Code:

This course, like all courses at Vanderbilt, is conducted under the Honor Code.

Studying: As you study for this class, I encourage you to to seek help from me, from Mr. de Wet, or from other classmates or friends.

Homework and Lab Assignments: I encourage working together. I also encourage you to talk with other classmates, as well as friends and acquaintances outside of class. You may discuss assignments, compare notes on how you are working a problem, and you may look at your classmates' work on homework assignments. But you must work through the problems yourself in the work you turn in: **Even if you have discussed the solution with others you must work through the steps yourself and express the answers in your own words. You may not simply copy someone else's answer.**

Tests and Exams: Tests and exams are different from homework and labs: **all work on tests and exams must be entirely your own**. **You may not work together with anyone or receive any help from anyone but meor Mr. de Wet on exams and tests (this includes the take-home final exam)**.

If you ever have questions about how the Honor Code applies to your work in this course, please ask me or Mr. de Wet. **Uncertainty about the Honor Code does not excuse a violation.**

5.1 Research Integrity

Beyond the University Honor Code, this course also emphasizes the scientific ethical principles of research integrity. Honesty is a very important part of research integrity, but it is only one part. Clearly, science cannot work if scientists are not scrupulously honest about the results of their research and there is no tolerance for scientists who lie. But research integrity goes much farther. Real science happens in the context of a scientific community and the integrity of this community is critical. The ethical principles of research integrity have grown over the centuries to protect the integrity of the scientific community. Indeed, the mathematician and poet Jacob Bronowski wrote, in his book, *Science and Human Values* (Harper & Row, 1956) that what makes science work and makes it great is much less about the intellectual brilliance and skills of individual scientists than about the ethical commitment to truth and human dignity by the community of scientists.

Science does not proceed only by making leaps of discovery but also by making useful mistakes and then discovering and correcting the errors in those mistakes. Because of this, scientific integrity requires scientists to be extremely transparent and forthcoming about all the details of their research. It is not enough to sincerely report a discovery or an idea in good faith, but one must also provide others with the tools to critically examine that discovery and

idea, and if a scientist learns, even many years later, that a report or discovery contained an error, they must correct the error and actively inform other scientists about it.

When a scientist discovers an error in their past work and does not promptly and actively correct it, other scientists may continue to rely on the truth of that result and thus waste time, effort, and money. Thus, both making one's own work available to others so they can have the opportunity to find errors, and also to promptly and publicly report any errors that one finds in one's own work are two critical pieces of research integrity.

Another aspect also involves the communal nature of science: None of us works in isolation, and every scientist's work builds on work by others. There are two reasons why it is critical to acknowledge the role of others' work in our own research reports: First, it is important to give others the credit for their contributions to our shared body of scientific knowledge. Secondly, it is important for others to know where the data and methods we use come from. If I use someone else's data or methods for an analysis and it later turns out that there were problems with their data or methods, then it is important for people reading my work to be able to examine my work and evaluate how those errors might affect my own results.

I want to emphasize that these considerations about research integrity are not just negative things. They are very positive, which is why so many researchers are embracing them. **By being transparent and forthcoming, and by encouraging others to reproduce your research results, you can enhance your reputation**, both for honesty (you show that you have nothing to hide) and for being a good citizen of the scientific community by making it easy for other researchers to learn from your work and build on it to make new discoveries and build new and more powerful tools for analyzing data.

Where this is relevant to this course on Global Climate Change is in our practice of reproducible research in the laboratory portion of the course. Making our work, however humble, fully open and transparent so that others may examine it, criticize it, or build on it to develop new tools and make new discoveries is an essential part of research integrity.

In your lab reports it will be important for you to document where the data you worked with comes from (this will mostly be clearly spelled out in the assignments) and what methods you used to analyze it. Using the tools of R and RMarkdown will make it easy to almost automatically include this kind of transparency in your reports. As you do this throughout this course, you will learn the best practices adopted by the scientific community and develop habits of openness, transparency, and reproducibility for any research you do in the future in any area of society, whether in science, journalism, business, or other endeavors.

6 Final Note:

I have made every effort to plan a busy, exciting, and instructive semester. I may find during the term that I need to revise the syllabus to give more time to some subjects or to pass more quickly over others rather than covering them in depth. Many topics we will cover are frequently in the news. Breaking news may warrant a detour from the schedule presented on the following pages. Thus, while I will attempt to follow this syllabus as closely as I can, you should realize that it is subject to change during the semester.

7 Meet Your Professor

Jonathan Gilligan has worked in many areas of science and public policy. His past research includes work on laser physics, quantum optics, laser surgery, electrical properties of the heart, using modified spy planes to study the ozone layer in the stratosphere, and connections between religion and care for the environment.

Professor Gilligan is Associate Professor of Earth & Environmental Sciences, Associate Professor of Civil & Environmental Engineering, and the director of the Vanderbilt Climate and Society Grand Challenge Initiative, which is working to integrate research, teaching, and public outreach about climate change across the natural sciences, social sciences, and humanities.

His current research investigates the role of individual and household behavior in greenhouse gas emissions in the United States; how "smart cities" can use technology to reduce environmental footprints and promote health and citizen empowerment; water conservation policies in American cities; vulnerability and resilience to environmental stress in South Asia; and developing new directions for climate policy in the US.

Professor Gilligan and Professor Michael Vandenbergh won the 2017 Morrison Prize for the highest-impact paper of the year on sustainability law and policy. Gilligan and Vandenbergh's book, *Beyond Politics: The Private Governance Approach to Climate Change* (Cambridge University Press, 2017), was named by *Environmental Forum* as one of the most important books on the environment of the last 50 years.

Apart from his academic work, Professor Gilligan dabbles in writing for the theater. His stage adaptation of Nathaniel Hawthorne's *The Scarlet Letter*, co-written with his mother Carol Gilligan, has been staged at The Culture Project in New York City, starring Marisa Tomei, Ron Cephas Jones, and Bobby Cannavale, and was later performed at Prime Stage Theatre, Pittsburgh and in a touring production by The National Players. Most recently, it was performed as the principal fall 2019 production of the Fullerton College Classic Dramatic Series in Fullerton CA, directed by Michael Mueller, and was also chosen by the Classic Repertory Company in Watertown, MA, for its 2019–2020 repertory season.

Prof. Gilligan and Carol Gilligan also wrote the libretto for an opera, *Pearl*, in collaboration composer Amy Scurria, and producer/conductor Sara Jobin, which was performed at Shakespeare & Company in Lenox MA, starring Maureen O'Flynn, John Bellemer, Marnie Breckenridge, John Cheek, and Michael Corvino, and in Shanghai China, starring Li Xin, Wang Yang, John Bellemer, and Lin Shu.

Schedule of Classes (Subject to Change)

IMPORTANT NOTE: This schedule gives a rough indication of the reading for each day. See the assignment sheets posted on Brightspace for the detailed daily assignments.

Date	Topic	Reading
Mon., Jan. 25	Introduction	No reading
Wed., Jan. 27	What is Climate Change?	*Forecast* Ch. 1, *Casino* Ch. 1–2
Fri., Jan. 29	Energy Balance and Climate	*Forecast* Ch. 2–3 pp. 9–23
Mon., Feb. 1	Greenhouse Effect	*Forecast* Ch. 3 pp. 23–26
Wed., Feb. 3	Greenhouse Gases	*Forecast* Ch. 4
Fri., Feb. 5	Vertical Structure of the Atmosphere	*Forecast* Ch. 5
Mon., Feb. 8	Review of Greenhouse Effect	No reading
Wed., Feb. 10	Feedbacks	*Forecast* Ch. 7 pp. 73–81
Fri., Feb. 12	Ocean and Biosphere Feedbacks	*Forecast* Ch. 7 pp. 81–84, Handouts (on Brightspace)
Mon., Feb. 15	The Carbon Cycle: Ocean and Biosphere	*Forecast* Ch. 8 pp. 89–97
Wed., Feb. 17	The Carbon Cycle: Mineral Weathering	*Forecast* Ch. 8 pp. 95–101
Fri., Feb. 19	Perturbing the Carbon Cycle	*Forecast* Ch. 10
Mon., Feb. 22	Climates of the Past	*Forecast* Ch. 11 pp. 135–145
Wed., Feb. 24	The Pleistocene Ice Ages	*Forecast* Ch. 7 p. 84, *Forecast* Ch. 8 pp. 93–97, *Forecast* Ch. 11 pp. 147–149, Handouts (on Brightspace)
Fri., Feb. 26	Review	No reading
Mon., Mar. 1	Climate Models	*Casino* Ch. 3–4
Wed., Mar. 3	Future Climate Change	*Casino* Ch. 5, *Forecast* Ch. 12 pp. 153–164
Fri., Mar. 5	Identifying Fallacies about Climate Change	TBA
Mon., Mar. 8	Climate Fallacies Game	No reading
Wed., Mar. 10	Uncertainty about Future Climates	*Forecast* Ch. 12 pp. 164–166, *Casino* Ch. 24, *Climate Fix* Ch. 1 pp. 1–24
Fri., Mar. 12	How Will Climate Change Affect Our Lives? (Part 1)	*Casino* 6–9
Mon., Mar. 15	How Will Climate Change Affect Our Lives? (Part 2)	*Casino* 10–12

Date	Topic	Reading
Wed., Mar. 17	Policy Myths	*Climate Fix* Ch. 2, *Casino* Ch. 25
Fri., Mar. 19	The Kaya Identity: Energy Use, Efficiency, and Conservation	*Climate Fix* Ch. 3, *Casino* Ch. 14
Mon., Mar. 22	Reducing Carbon Emissions: Bottom-Up Approaches	*Climate Fix* Ch. 4, Handouts (on Brightspace)
Wed., Mar. 24	Reducing Carbon Emissions: Top-Down Approaches	*Climate Fix* Ch. 4, Handouts (on Brightspace)
Fri., Mar. 26	The Cost of Reducing Emissions	*Casino* Ch. 14 pp. 157–165, *Casino* Ch. 15
Mon., Mar. 29	Goals of Climate Policy	*Casino* Ch. 17, *Climate Fix* Ch. 6
Wed., Mar. 31	Costs and Benefits	*Casino* Ch. 18
Fri., Apr. 2	Pricing Carbon	*Casino* Ch. 19
Mon., Apr. 5	Carbon Pricing Instruments	Handouts (on Brightspace)
Wed., Apr. 7	Discounting and the Value of Time	*Casino* Ch. 16, Handouts (on Brightspace)
Fri., Apr. 9	The Limits of Economic Approaches	Handouts (on Brightspace)
Mon., Apr. 12	The Case for Renewable Energy	Handouts (on Brightspace)
Wed., Apr. 14	The Case for Nuclear Energy	Handouts (on Brightspace)
Fri., Apr. 16	Geoengineering: Solar Radiation Management	*Climate Fix* Ch. 5 pp. 117–132, *Casino* Ch. 13 Read the whole chapter, but focus especially on pp. 152–156, Handouts (on Brightspace)
Mon., Apr. 19	Geoengineering: Carbon Dioxide Management	*Climate Fix* Ch. 5 pp. 132–142, *Casino* Ch. 14 pp. 165–168, Handouts (on Brightspace)
Wed., Apr. 21	Pragmatism and Climate Policy	*Casino* Ch. 23, *Climate Fix* Ch. 9
Fri., Apr. 23	Global Warming Gridlock	Handouts (on Brightspace)
Mon., Apr. 26	Beyond Gridlock: Second-Best Policies	Handouts (on Brightspace)
Wed., Apr. 28	Obstacles and Perspectives	*Casino* Ch. 26, Handouts (on Brightspace)
Fri., Apr. 30	Review	No reading